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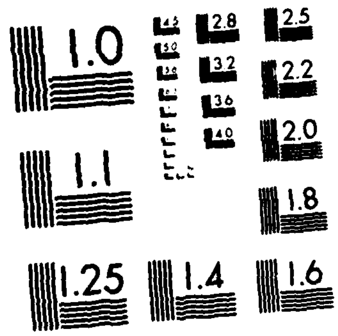

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Since the development of the clear-air Doppler radar technique (also called the wind-profiling or MST-radar technique) at Jicamarca, Peru (Woodman and Guillen, 1974), and Sunset, Colorado (Green et al., 1975), it has been applied to a wide range of meteorological problems (see, e.g., Liu and Kato, 1985). Despite this rapid progress, research on some important problems has been frustrated by the fact that most clear-air Doppler radars are near mountains. The resulting orographic effects act as geophysical noise on observations of other processes. These effects are especially serious for studies of the vertical component of motion. For example, Ecklund et al. (1982) found that when the wind flowed over the mountains, the variance of the vertical velocity was strongly correlated with the wind speed. Nastrom et al. (1985) found that they could extract the small synoptic-scale vertical velocity only when the horizontal wind was not from the direction of nearby mountains. Following their suggestion, we have constructed a new clear-air Doppler radar, called the Flatland radar, in very flat terrain near Champaign-Urbana, Illinois. We find that the vertical velocity field over very flat terrain is indeed quite different from that near rough terrain, and we present observations that suggest that the vertical velocity due to other processes, such as synoptic-scale motions and gravity waves, can be studied by clear-air Doppler radars in very flat terrain.

To be presented at the Symposium on Lower Tropospheric Profiling: Needs and Technologies, May 31-June 3, 1988, Boulder, Colorado

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MEASUREMENT OF VERTICAL VELOCITY USING CLEAR-AIR DOPPLER RADARS

by

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1. INTRODUCTION

Since the development of the clear-air Doppler radar technique (also called the wind-profiling or MST-radar technique) at Jicamarca, Peru (Woodman and Guillen, 1974), and Sunset, Colorado (Green et al., 1975), it has been applied to a wide range of meteorological problems (see, e.g., Liu and Kato, 1985). Despite this rapid progress, research on some important problems has been frustrated by the fact that most clear-air Doppler radars are near mountains. The resulting orographic effects act as geophysical noise on observations of other processes. These effects are especially serious for studies of the vertical component of motion. For example, Ecklund et al. (1982) found that when the wind flowed over the mountains, the variance of the vertical velocity was strongly correlated with the wind speed. Nastrom et al. (1985) found that they could extract the small synoptic-scale vertical velocity only when the horizontal wind was not from the direction of nearby mountains. Following their suggestion, we have constructed a new clear-air Doppler radar, called the Flatland radar, in very flat terrain near Champaign-Urbana, Illinois. We find that the vertical velocity field over very flat terrain is indeed quite different from that near rough terrain, and we present observations that suggest that the vertical velocity due to other processes, such as synoptic-scale motions and gravity waves, can be studied by clear-air Doppler radars in very flat terrain.

2. EXPERIMENTAL DESIGN

The Flatland Radar is located at 40.5°N, 88.4°W, 212m above mean sea level (MSL), about 8km west of the Champaign-Urbana Airport. The radar operates at a frequency of 49.8MHz (wavelength, 6.02m), with a pulse length and the range resolution of 750m. The 3dB, two-way beamwidth is 3.2°. To minimize contamination of vertical velocity measurements by horizontal winds, the antenna was carefully leveled to within 0.02° from the vertical. The Doppler spectra have a velocity resolution of $5 cm s^{-1}$ and an unaliased velocity range of $\pm 3.2 \, m s^{-1}$. The Flatland radar has been measuring the vertical velocity every 153 seconds almost continuously since March 2, 1987. The second phase of the Flatland radar, with steerable oblique beams to measure both components of the horizontal wind, will be implemented in early 1988. A more detailed description of the radar and some preliminary results are given in Green et al., 1988.

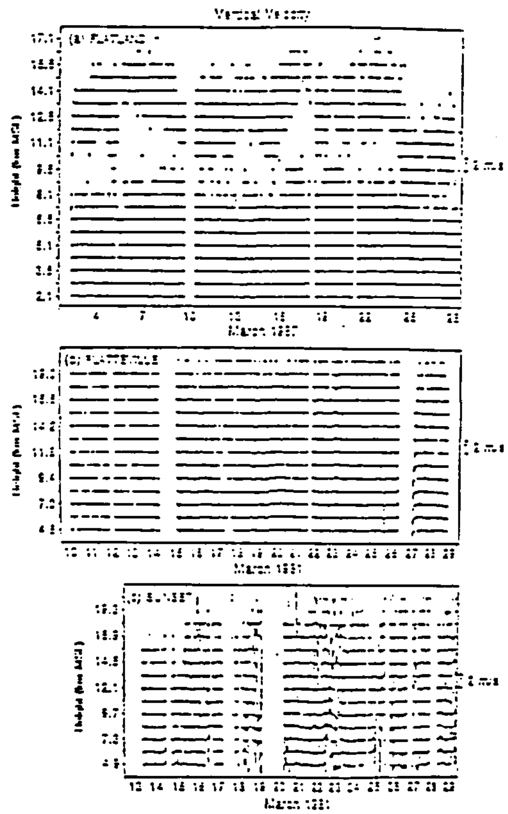

Figure 1. Radar vertical velocities averaged over fifteen-minute periods: (a) Flatland radar during March 1987; (b) Platteville radar during March 1981. (Panels (b) and (c) are from Ecklund et al., 1982.)

3. RESULTS

Figure 1 presents time series of 15-minute averages of the vertical velocity in each range gate of three radars, each located in a different kind of terrain. Panel (a) is from the Flatland radar and panels (b) and (c) are from the Platteville and Sunset radars in Colorado, 80 and 16km east of the crest of the Front Range (~ 4000m MSL), respectively. In the Flatland time series the smaller upper height limit and the data gaps around 10km are thought to be due to a smaller signal-to-noise ratio.

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In the Colorado time series in Figures 1(b) and 1(c) there is a striking alternation of "active" periods with large variance and "quiet" periods with relatively small variance. Ecklund et al. (1982) showed that the variance is highly correlated with the strength of the 5km zonal wind flowing over the Front Range, and they concluded that the active periods are mostly due to mountain waves. In contrast, the variance in the Flatland time series in Figure 1(a) is nearly always small, comparable with that during the quiet periods at Platteville and even smaller than the quiet periods at Sunset.

Mountains have similar effects on short-period vertical motions. Figure 2 shows frequency spectra during spring 1987 from the 5.2km range gate at Flatland, plotted with thick curves, together with spectra taken in southern France during ALPEX (Ecklund et al., 1985), plotted with thin curves. The spectra are stratified into quiet days, when the lower-tropospheric winds were light, less than ∿ 5m/s, and active days, when the winds were greater than ∿ 20 m/s. On quiet days both the ALPEX and Flatland spectra are flat to periods just less than the buoyancy frequency at about 10 minutes. The Flatland active-days spectrum is similar, but flatter and slightly raised. But at ALPEX the strong winds were northerly mistral winds that passed over nearby low mountains, and the ALPEX active-day spectra are much steeper, with a slope as negative as -5/3 (indicated by the thick straight line) and with amplitudes much larger at all frequencies.

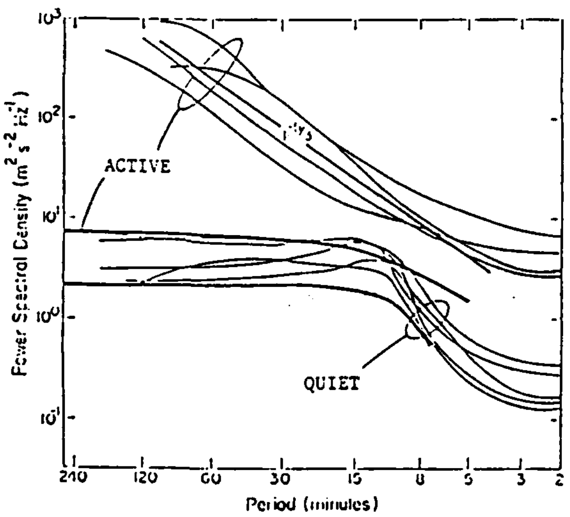

Figure 2. Frequency spectra of vertical velocity fluctuations. The two thick curves are from Illinois (Flatland) and the thin curves, from southern France (ALPEX). The heavy straight line labeled $F^{-5/3}$ is an approximation to the ALPEX active-days spectra. The Flatland spectra are from the 5.2km range gate and are the average of 13 and 9 spectra, respectively. The ALPEX spectra are the average of four 750m range gates centered from 3.85 to 6.10km.

Moreover, the slight change in shape of the Flatland spectra with increasing wind speed is not inconsistent with the change predicted due to Doppler shifting of an intrinisic gravity wave spectrum by the background wind (Fritts and VanZandt, 1987). This suggests that under these conditions the vertical motions are predominantly due to propagating gravity waves, with only small contributions from other processes.

4. CONCLUSIONS

These results show that vertical motions near rough terrain are often dominated by orographic effects, at all periods ranging from minutes to many hours. The absence of such effects over very flat terrain suggests that clear-air Doppler radars can be used to study vertical velocities due to other processes, including synoptic-scale motions and propagating gravity waves.

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